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CORRELATION BETWEEN BODY MASS INDEX AND BLOOD PRESSURE INDICES, HANDGRIP STRENGTH AND HANDGRIP ENDURANCE IN UNDERWEIGHT, NORMAL WEIGHT AND OVERWEIGHT ADOLESCENTS

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Abstract : In the present study, we investigated the correlation between body mass index (BMI), blood pressure (BP) indices and indices of physical fitness in apparently healthy subjects aged 14–18 years. We obtained data from 145 (105 males and 40 females) and assessed the correlation between BMI, and heart rate, systolic pressure (SP), diastolic pressure (DP), pulse pressure (PP), mean arterial pressure (MP), rate-pressure product, endurance in the 40 mm Hg test, handgrip strength (HGS), and handgrip endurance. Subjects with BMI <18.5 kg/m^2, 18.5–25 kg/m^2 and >25 kg/m^2 were classed as underweight (65 males and 9 females), normal weight (27 males and 20 females), and overweight (13 males and 11 females) respectively. In view of gender differences in autonomic regulation, data of male and female subjects were analyzed separately. We used analysis of variance to compare differences between the three groups. Correlation between BMI and other indices was tested using Pearson's correlation coefficient. A P value <0.05 was considered statistically significant. Both SP and DP were highest in overweight and least in underweight male subjects (P<0.05 for both), whereas in females, differences in DP alone were statistically significant (P<0.05). In underweight male subjects, there was a positive correlation between BMI and SP, DP, PP, MP and HGS (P<0.05 for all). There was a positive correlation between BMI and SP in overweight male subjects (r = 0.5 P = 0.07, n = 13). A positive correlation was observed between BMI and rate-pressure product (r = 0.5, P = 0.45, n = 11) and BMI and HGS (r = 0.6, P = 0.05, n = 11) in overweight females. Our observations indicate that there are gender differences in the correlation between BMI and BP indices especially in underweight and overweight subjects. The observed differences between the three groups and gender differences in correlation between BMI and BP indices may be due to differences in autonomic function and or energy metabolism.

Key words : heart rate nutrition rate-pressure product

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INTRODUCTION

Blood pressure (BP) is regulated by activity in the autonomic nervous system (1). Obesity is associated with sympathetic activation and is the leading risk factor for development of hypertension (2). The use of body mass index (BMI) for the prediction of risk factor clustering among children and adolescents has significant clinical utility (3). In a large cross sectional study of adolescents, BMI has been shown to be a better index of body fatness compared to waist-hip ratio (4). In the present study, we tested the hypothesis that there is a correlation between BMI and BP indices viz. systolic pressure (SP), diastolic pressure (DP), mean pressure (MP), heart rate (HR), and rate-pressure product (RPP) in apparently healthy adolescents. Since skeletal muscle function is likely to be influenced by nutritional state as well as cardiorespiratory fitness, we also tested the correlation between BMI and the following three parameters viz. handgrip strength (HGS), handgrip endurance (HGE), and endurance in the 40 mm Hg test. Thus, the aim of the present study has been to assess the correlation between BMI and BP indices, handgrip strength, handgrip endurance, and endurance in the 40 mm Hg test in underweight, overweight and normal weight adolescents. The physiologic significance of the observed correlations is briefly discussed.

METHODS

Subjects

Subjects were classified into three groups based on BMI as follows: underweight (BMI <18.5 kg/m^2), normal weight (BMI 18.5–25 kg/m^2), and overweight (BMI >25 kg/m^2). The age, height, weight and BMI of the subjects in the three groups is given in Tables I (for males) and Table II (for females). None of the subjects were taking any medication and none had a significant medical history. All of them had a normal physical examination. Subjects with history and or clinical evidence of acute medical illnesses were excluded.

Testing protocol : The Institute Ethics Committee of JIPMER approved the study protocol. All subjects' parents/guardians gave informed consent. All parameters were obtained in the school in which the subjects were studying, between 10 am and 12 noon, 2–3 h after a light breakfast. One of the authors made all observations. Height, weight and mid-arm circumference were recorded and the tests were done in the following sequence after familiarizing the subjects with the testing procedures.

1. Resting HR and BP in the sitting position
2. 40 mm Hg test
3. Determination of HGS
4. Determination of HGE

After a rest period of 5 minutes, HR and BP were determined from the right arm using a noninvasive BP monitor (OMRON Inc., Japan) with the subject comfortably seated and back supported. This instrument measures BP by oscillometric method. At least two readings were taken at an interval of at least 5 minutes and the average of the two readings used for analysis. Pulse pressure (PP) was determined as the difference between SP and DP. MP was calculated as DP + 1/3 PP. RPP was calculated as SP × HR × 10^{-2}. Respiratory muscle strength was assessed from the endurance in the 40 mm Hg test. This test was done by asking the subject to blow forcefully into a mouthpiece attached to a manometer and maintain an expiratory pressure of 40 mm Hg, after a tidal inspiration. The duration for which the subject could maintain this pressure was noted. After 3 minutes rest, HGS was determined using a handgrip dynamometer as the maximal voluntary contraction sustained for at least 3 seconds. HGE was determined by asking the subject to maintain 1/3 of maximal voluntary contraction for as long as he/she could.

Statistical analysis :

All data are expressed as means ± SD. In both males and females, differences between underweight, normal weight and overweight groups were tested using one-way analysis of variance followed by Tukey-Kramer's multiple comparisons test. In each group, differences between male and female subjects were analyzed by unpaired *t*-test. Correlation between BMI and all other parameters was assessed by calculating Pearson's correlation coefficient. A two-tailed P value less than 0.05 was considered statistically significant.

RESULTS

Results are given in Tables I–III. Subjects' anthropometric characteristics, resting HR, BP, handgrip strength, handgrip endurance and performance in the 40 mm Hg test are given in Tables I and II. The correlation between BMI and various parameters is presented in the form of a correlation matrix in Table III. In view of the possibility that there could be gender differences in regulation of cardiovascular autonomic function (5–8), we have analyzed data in males and females separately.

TABLE I : Anthropometric characteristics, resting blood pressure, heart rate, handgrip strength and handgrip endurance of male subjects. Data are expressed as means ± SD.

	Underweight (n = 65)	*Normal weight (n = 27)*	*Overweight (n = 13)*	*P value*
Age (yr)	15.7±0.8	15.9±0.7	16±1.2	0.31
Weight (kg)	45.2±5.3	57.5±7	80±15	<0.0001
Height (m)	1.65±0.07	1.68±0.08	1.68±0.1	0.07
Body mass index (kg/m^2)	16.6±1.3	20.2±1.7	30.5±6	<0.0001
Heart rate (beats per minute)	81±11	80±9	81±15	0.91
Systolic pressure (mmHg)	101±12	105±11	117±11	<0.001
Diastolic pressure (mmHg)	59±8	65±9	76±8	<0.0001
Pulse pressure (mmHg)	42±8	41±8	41±10	0.69
Mean pressure (mmHg)	73±9	78±9	89±8	<0.0001
Rate-pressure product (units)	83±19	85±16	94±21	0.12
Endurance in 40 mmHg test (s)	29±15	36±22	24±5	0.21
Handgrip strength (mmHg)	211±45	238±41	220±72	0.06
Handgrip endurance (s)	89±30	92±34	104±40	0.31

TABLE II : Anthropometric characteristics, resting blood pressure, heart rate, handgrip strength and handgrip endurance of female subjects. Data are expressed as means ± SD.

	Underweight (n = 9)	*Normal weight (n = 20)*	*Overweight (n = 11)*	*P value*
Age (yr)	14.8±0.7	15.5±0.7	15.3±1	0.08
Weight (kg)	39.8±3.6	53.4±6.4	67±6.9	<0.0001
Height (m)	1.56±0.05	1.6±0.06	1.56±0.04	0.23
Body mass index (kg/m^2)	16.4±1.29	21.1±1.62	28±2.1	<0.001
Heart rate (beats per minute)	98±13	93±18	93±16	0.77
Systolic pressure (mmHg)	101±10	106±12	110±11	0.19
Diastolic pressure (mmHg)	62±7	69±12	74±8	0.03
Pulse pressure (mmHg)	39±7	37±9	36±7	0.68
Mean pressure (mmHg)	75±8	81±11	86±8	0.04
Rate-pressure product (units)	99±19	99±24	103±25	0.88
Endurance in 40 mmHg test (s)	37±24	34±26	27±11	0.54
Handgrip strength (mmHg)	159±40	155±30	175±62	0.48
Handgrip endurance (s)	81±25	98±42	102±37	0.42

TABLE III : Correlation between body mass index and various parameters in underweight (UW), normal weight (NW) and overweight (OW) subjects. Data are expressed as Pearson correlation coefficient. Sample size (n) is indicated within brackets.

Group, (n)	*Heart rate*	*Systolic pressure*	*Diastolic pressure*	*Pulse pressure*	*Mean pressure*	*Rate-pressure product*	*Endurance in 40 mm Hg test*	*Handgrip strength*	*Handgrip endurance*
UW males (65)	0	0.4**	0.4**	0.3**	0.4**	0.2	0.1	0.5**	0.1
NW males (27)	0.2	0.01	0.3	–0.3	0.2	0.1	0.1	–0.3	–0.2
OW males (13)	0.2	0.5	0.3	0.4	0.4	0.5	0.2	0.3	–0.1
UW females (9)	0.1	0	–0.2	0.1	–0.1	0	–0.4	–0.02	–0.2
NW females (20)	0.1	–0.2	0.4	–0.1	0.1	–0.1	0.02	–0.3	0
OW females (11)	0.4	0.3	0.1	0.4	0.2	0.5	0.2	0.6*	–0.2

*P<0.05, **P<0.01, ***P<0.001.

Males : There was a significant difference between the three groups in terms of BMI (P<.0001 for both males and females). Whereas SP, DP and MP were lowest in underweight and highest in overweight subjects (P<0.05 for each), HR, PP and RPP were similar in the three groups (P>0.1 for each). Differences between the three groups in terms of performance in the 40 mm Hg test were not statistically significant (P>0.1). HGS was highest in normal weight male subjects; however, differences were not statistically significant (P = 0.06). HGE was similar in the three groups.

Females : There were significant differences in DP (P<0.05) between the three groups, i.e., it was highest in overweight subjects and least in underweight subjects; however, differences in SP did not quite reach statistical significance (P = 0.19), although SP was highest in overweight subjects.

Differences in MP were similar to that of DP ($P<0.05$). No significant differences were noted between the three groups in either the endurance in the 40 mm Hg test, HGS or HGE.

Important correlations : There were statistically significant positive correlations between BMI and all BP indices except rate-pressure product in underweight male subjects. In marked contrast, no significant correlations were observed between BMI and BP indices in underweight female subjects. The correlation between BMI and HGS was highest in overweight females ($r = 0.6$) and underweight males ($r = 0.5$) respectively. A modest positive correlation between BMI and SP ($r = 0.5$), and BMI and rate-pressure product ($r = 0.5$) was observed in overweight male subjects although it was not statistically significant. In contrast, in overweight female subjects, BMI correlated with rate-pressure product ($r = 0.5$), although it correlated more closely with HR rather than SP.

Comparisons between males and females with similar nutritional status : In underweight as well as normal weight groups, differences in resting HR and RPP between males and females were statistically significant ($P<0.05$ for all). However, in the overweight subjects, the difference in resting HR did not quite reach statistical significance ($P = 0.07$). Further, there were no significant differences in SP, DP, and PP between males and females in the underweight, normal weight and overweight groups. As expected, handgrip strength was markedly greater in males compared to females in both underweight and normal weight subjects ($P<0.05$ for both); however, in overweight subjects, differences in handgrip strength were not statistically significant. Endurance in the 40 mm Hg test was similar in both genders belonging to underweight, normal weight and overweight groups.

DISCUSSION

In both males and females, we found that SP and DP were highest in overweight subjects, intermediate in normal weight subjects and least in underweight subjects. This is possibly due to differences in sympathetic tone between underweight and overweight subjects. However, PP was similar. Assuming that arterial compliance was not different between the groups, this suggests that stroke volume is also similar. Also, HR was similar. Thus, we have indirect evidence that cardiac output is not significantly different between the three groups. Thus, differences in BP could be largely due to differences in total peripheral resistance, which in turn is greatly influenced by tonic sympathetic control of resistance vessels. Our results indirectly suggest that the higher BP in overweight subjects is due to heightened sympathetic vascular tone (9).

We assumed that when effort is maximal, endurance in the 40 mm Hg test is directly related to cardiorespiratory fitness and is influenced by respiratory muscle strength. However, even amongst normal weight subjects, the dispersion of data is considerable and interpretation is therefore difficult. This may partly be due to the fact that this is an effort dependent parameter. Results of a population study by Lee et al (10) indicate that in men aged 30-60 yr, cardiorespiratory fitness as measured by maximal oxygen uptake treadmill testing and body fatness are nearly independent of each other.

HGS, a simple index of skeletal muscle function and a functional index of nutritional status (11), is influenced by effort, skeletal muscle bulk and contractility. From what we have observed, HGS, which we measured while the subject sustains a maximal voluntary contraction for 3 seconds, is not affected by body weight per se. Indeed, it was demonstrated that underweight subjects have a MVC similar to that of normal

weight subjects while it was considerably reduced in chronically energy deficient subjects (12). In a large cross sectional study of elderly women, only statistically insignificant differences in muscle strength were observed between underweight, normal weight and overweight subjects after adjustments for age, height, appendicular skeletal mass indicating that HGS is influenced significantly by factors other than body weight. (13). Although HGE would be expected to be considerably influenced by effort, cardiorespiratory fitness, skeletal muscle function, we did not observe a statistically significant difference between the groups. Indeed, an earlier onset of fatigue during isotonic exercise has been demonstrated in chronically energy deficient subjects (14).

Correlations between BMI and other parameters: It is interesting to note that there is a correlation between BMI and systolic pressure in both underweight and overweight males but not normal weight males. Differences in hemodynamics may account for such differences. The positive correlation between BMI and hyperdynamic circulation (increased PP and HR), although statistically insignificant in our series, has also been reported previously (15). In underweight male subjects, fat mass is very less and thus it is not difficult to appreciate the positive correlation between BMI and HGS. In contrast, there was no significant correlation between BMI and BP indices in underweight females. Surprisingly, there was no correlation between BMI and HGS in underweight female subjects.

In conclusion, our results indicate that systolic pressure is linearly related to BMI in underweight and overweight males, and overweight females. Thus, there are also gender differences in correlation between BMI and BP indices. Although, there are statistically significant correlations between BMI and BP indices, the correlation is at best modest and it is likely that several factors besides BMI influence BP indices. Indeed, there is evidence that genetic factors account significantly for the correlation observed between BMI and BP (19). Obesity is associated with insulin resistance and hyperinsulinemia is associated with excessive sympathetic activity (2, 20–22). The observed differences between the underweight, normal weight and overweight subjects may possibly be due to differences in cardiovascular autonomic control and or energy metabolism.

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